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# ERRORS DUE TO TERRESTIAL ROTATION RESTITUTION OF LOCALIZATION

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# ERRORS DUE TO TERRESTRIAL ROTATION

# RESTITUTION OF LOCALIZATION

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February, 1966

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## I. ERRORS DUE TO TERRESTRIAL ROTATION

During the time of interrogation T between two positions $S_1$ and $S_2$ of the satellite, the balloon is carried along by the rotation of the earth and describes an arc $B_1 B_2$ whose length depends on the latitude. Any localization directly utilizing the distances $d_1$ and $d_2$ ($S_1 B_1$ and $S_2 B_2$) will therefore be affected by a systematic error. For an accurate procedure, we must have available, at the instant $t_2$, not only $d_2$ but also a distance $d_1^*$ ($d_1$ corrected) which will be equal to $S_1 B_2$ (Figure 1). The error will be as much larger as the bases are closer toward the limits of visibility. However, since the angular velocity of terrestrial rotation is known, it is possible to correct these errors, e.g., by the procedure described below:

Let $B_c$ be the first estimate of the position of the balloon made directly from $d_1$ and $d_2$ (the balloon $B_c$ is then localized at the intersection of three spheres: the "sphere" of the balloons, and the spheres $S_1$, $d_1$ and $S_2$, $d_2$). Although inaccurate, this first estimate will give an idea of the latitude $\varphi$ of the balloon and consequently of the deviation $d_1^* - d_1$. We carry out on $B_c$ the rotation $- \omega_o T$ in order to obtain the estimated position $B_c'$ at the instant $t_1$. We then calculate the distance $d_c$ and $d_c'$ ($S_1 B_c$ and $S_1 B_c'$). A first approximation

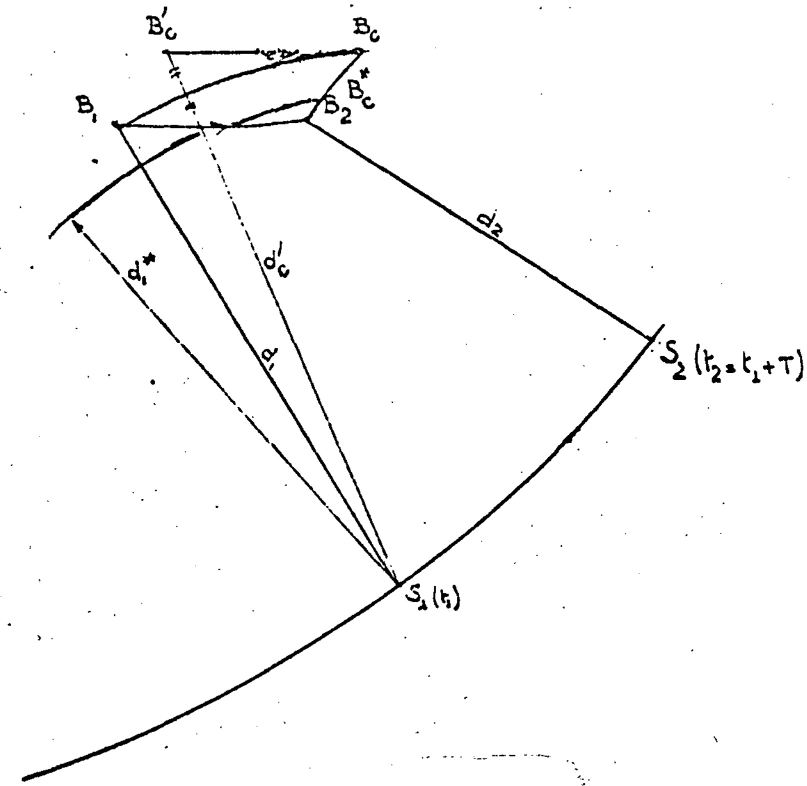


Figure 1

of the error for $d_1$ (due to the rotation of the earth) is equal to $d_c - d_c'$. We consequently relocalize by utilizing the distances $d_1 = d_1 + d_c - d_c'$, $d_2$, and thus obtain a better estimate of $B_c$ which makes it possible to evaluate the correction for $d_1$ still better, and continue to do so. This iterative process may be automatically arrested when the deviation between two successive localizations will be less than a certain number of meters. We shall see that the process actually converges rapidly.

## II. CORRECTION OF ERRORS

### 2.1 Notations

Correction of errors therefore requires us to be able to effect a first localization $B_c$ of the balloon if we know $t_1$, $t_2$ and $d_1$, $d_2$. To solve this problem, we use the following trihedra (Figure 2):

a) The inertial trihedron XYZ where OZ passes through the axis of the poles and where OX is an inertial axis of reference passing through the vernal point.

b) The plane of the orbit is referenced by its inclination $\underline{i}$ and the inertial longitude $\Omega$ of the ascending node. The movement of the satellite in the plane of the orbit is referenced in relation to the trihedron X, Y, Z, where OX passes through the ascending node and OZ is carried by the vector $\Omega_s$. The formulas of transformation from one to the other system are defined in Table I.

| | X | Y | Z |
|---|---|---|---|
| x | $\cos\Omega$ | $\sin\Omega$ | 0 |
| y | $-\cos i \sin\Omega$ | $\cos i \cos\Omega$ | $\sin i$ |
| z | $\sin i \sin\Omega$ | $-\sin i \cos\Omega$ | $\cos i$ |

Table 1

Generally, the inertial longitude $\Omega$ of the ascending node will be a function of time as well as the radius of the orbit $R_S$ and $\Omega_s$.

c) The rotation of the earth is easily expressed in the absolute trihedron XYZ since we have, between the coordinates of the balloon $B_1$ at the instant $t_1$ and those of the same balloon $B_2$ at the instant $t_2$ where $\omega_o$ designates the angular velocity of terrestrial rotation:

$$\left.\begin{aligned} X_{B_2} &= X_{B_1}\cos\omega_0 T - Y_{B_0}\sin\omega_0 T \\ Y_{B_2} &= X_{B_1}\sin\omega_0 T - Y_{B_0}\cos\omega_0 T \\ Z_{B_2} &= Z_{B_1} \end{aligned}\right\} \mathrm{II}$$

Without diminishing the general character of the problem, we can neglect the precession of the orbit and the advance of the perigee in regard to the errors of localization and during the time of visibility in one orbit[1]. Under these conditions, we can take the axis OX as the inertial axis OX which simplifies the transformation formulas I ($\Omega = 0$).

In order to take into account the conditions of visibility, let us assume that the balloon is at the instant $t = 0$ at $B_o$ at latitude $\varphi$ in the plane XZ (Figure 3) and that the first interrogation is made exactly at the limit of visibility.

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[1] We shall return to this problem in paragraph 3 on restitution of the data.

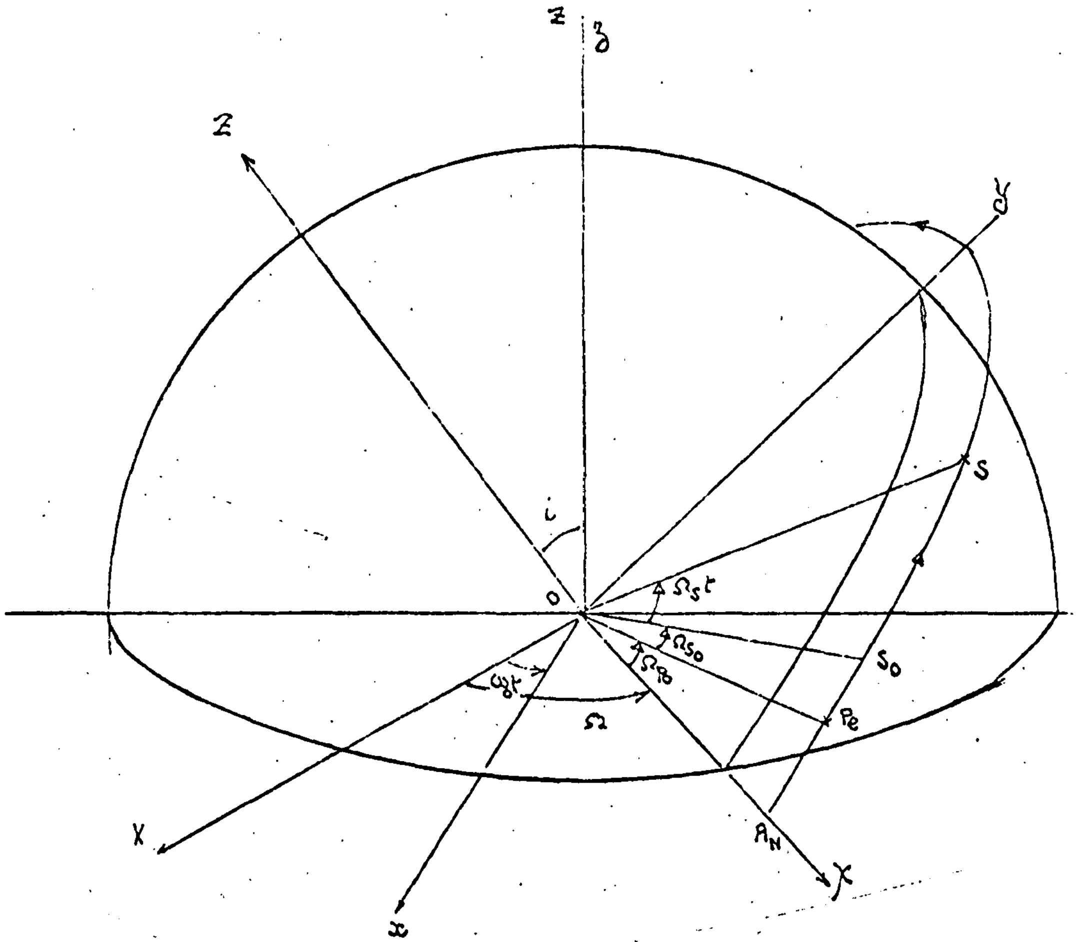



Figure 2

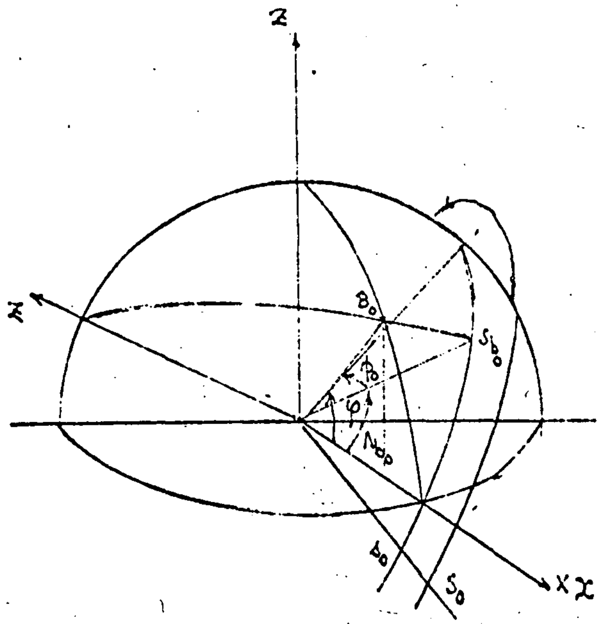



Figure 3

At that instant, the balloon is located at a distance $\phi_o$ from the earth Trace which is such that

$$R \sin \phi_o = R \sin \varphi \cos i$$
$$\phi_o = \text{Arc} \sin(\sin \varphi \cos i)$$

- At an elevation e, the angle to the center of visibility is ô such that

$$\cos O = \rho \cos^2 e + \sin e \sqrt{1 - \rho^2 \cos^2 e}$$

and the trace of the satellite at $s_o$ consequently is such that

$$s_o s_{b_o} = \gamma_o$$
$$\gamma_o = \text{arc} \cos(\cos O / \cos \phi_o) .$$

In regard to the polar angle of $s_{bo}$ in the plane XY, this is defined by $\Lambda_{b_o} = \text{arc tg}(\sin i \,\text{tg}\, \varphi)$

The position of the satellite at the start of visibility therefore is

$$\Lambda_o = \Lambda_{b_o} - \gamma_o = \text{arc tg}(\sin i \,\text{tg}\, \varphi) - \text{arc} \cos(\cos O / \cos \phi_o)$$

We therefore know the coordinates of the satellite and of the balloon at the instant 0 from the first interrogation. At the instant T, we will have the coordinates of the balloon by utilizing formulas (1) and those of the satellite by substituting $\Lambda_0$ for $\Lambda_0+\Omega_S T$.

During successive interrogations, we must check, in consideration of the simultaneous displacement of the balloon and of the satellite, that the conditions of visibility remain satisfied. It is sufficient for this to express that the angle $(OS_n, OB_n)$ is less than 0 and consequently that

$$\cos\alpha = \left(X_{B_N} X_{S_N} + Y_{B_N} Y_{S_N} + Z_{B_N} Z_{S_N}\right)/RR_S > \cos 0$$

which makes possible an easy test.

2.2 Localization

The problem is then posed as follows: Knowing the positions of the satellite $S_1$ and $S_2$ at the instants of interrogation serving as basis, and knowing the distances $d_1$, $d_2$ between satellite and balloon at these instants, find the position of the balloon on the earth.

If the location will ultimately be made in the system XYZ, we shall begin by referencing the balloon in a new system $(\xi, \eta)$ defined in Figure 4, where R is the radius of the sphere of the balloons and $R_S$ is the radius of the orbit. The figure lies in the plane of the orbit and the two positions $S_1$ and $S_2$ of the satellite are separated by the interval between interrogation T $\Omega_S T = 2\mu$. The two spheres $S_1$ $d_1$ and $S_2$ $d_2$ intersect in a plane perpendicular to $S_1$ $S_2$ referenced by the distance mk

$$m_K = \xi_K = \left(d_1^2 - d_2^2\right)/4R_S \sin\mu \qquad (3)$$

The radius r = km of the circle of intersection of the two spheres is equal to

$$r^2 = d_1^2 - (\xi_K + R_s \sin\mu)^2 \qquad (4)$$

This circle lies in a plane $\Pi$ which intersects the sphere of the balloons along a circle $\Gamma'$ with its center at H, and with radius $r_b$ such that

$$r_b^2 = R^2 - \xi_K^2 \qquad (5)$$

The balloon is then localized on this circle $\Gamma'$ by a polar angle $\psi_B$

$$bK = r_b \cos\psi_B = \frac{R_s^2 \cos^2\mu - r^2 + r_b^2}{2R_s \cos\mu}$$

$$\cos\psi_B = \frac{r_b^2 - r^2 + R_s^2 \cos^2\mu}{2 r_b R_s \cos\mu} \qquad (6)$$

From the datum of $r_b$ and of $\psi_B$ we deduce the coordinates of the balloon in the system $\xi\ \eta\ \zeta$

$$\left.\begin{aligned} \xi_b &= \frac{2(R_s^2 + R^2) - (d_1^2 + d_2^2)}{4R_s \cos\mu} \\ \eta_b &= \xi_K \\ \zeta_b &= r_b \sin\psi_B \end{aligned}\right\} \qquad (7)$$

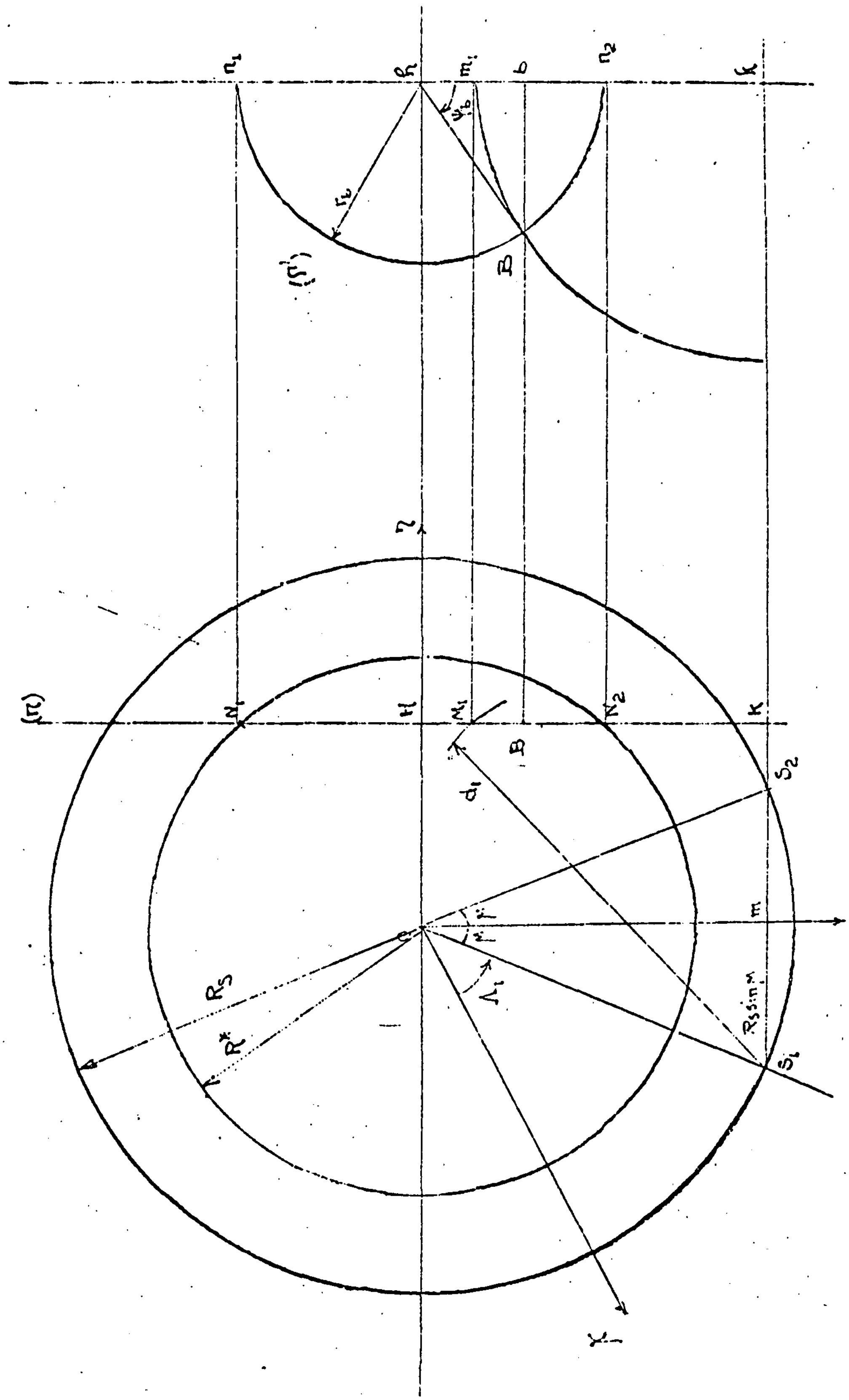


Figure 4

The coordinates of the balloon in the trihedron XYZ are calculated from the transformation formulas

$$\begin{aligned} x &= \xi \cos(\Lambda_1+\mu) - \eta \sin(\Lambda_1+\mu) \\ y &= \xi \sin(\Lambda_1+\mu) + \eta \cos(\Delta_1+\mu) \\ z &= \zeta \end{aligned} \tag{8}$$

With this, the system 2 makes possible localization in the trihedron.

Subsequent calculation for improvement of localization does not raise any difficulties. Its large lines will be found in the annex with the calculation program.

2.3 Results

2.3.1 Influence of the Position of the Bases (cf. program in annex)

It has already been pointed out that, when the bases are at the limit of visibility, the error due to terrestrial rotation may become large. It is thus necessary to test the error and the quality of the proposed iterative process.

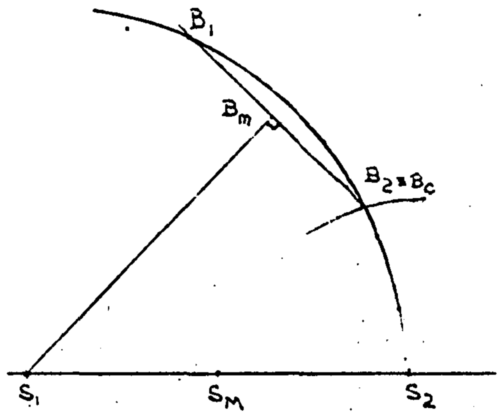
For this purpose, we utilized the calculation program Number 1 which will be found in the annex, by effecting the localization on all possible bases.

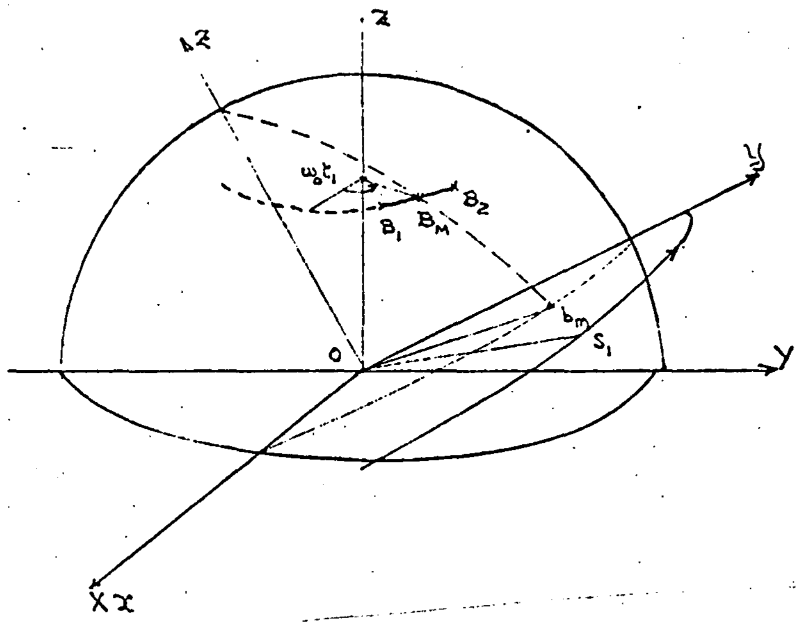
When the interval between interrogation is short in relation to the time of visibility (and we shall see that there is no advantage in increasing this interval too much by reason of the wind), the errors of localization at the limit of visibility become considerable.

The diagrams 1 and 2 are characteristic in this respect: for an orbit of 900 km and inclined at $44^{\circ}$, the error produced has been plotted on the first localization ($B_c$ - $B_v$) for balloons at various latitudes on the earth and for intervals between interrogation respectively equal to 100 and 200 sec. The localization was made on all successive bases satisfying the conditions of visibility. The deviation between the mean position of the balloon during two successive interrogations in relation to the center of the base utilized has been plotted as abscissa and the error in kilometers on the ordinate. We find that this error may reach 500 km!

The condition for making the error due to terrestrial rotation zero is the necessity for the sphere with center $S_1$ and with radius $S_1 B_1 = d_1$ to also pass through $S_2$. We then have $d_c = d_1 = S_1 B_2$. This requires that $S_1$ be located at the intersection of the orbit and of the mean geographic meridian plane of the balloon $B_M$.

The sequential process of interrogation conditions that this disposition may not correspond to an effective interrogation. The theoretical curve of the error as a function of the angle of the "orbital" meridians of $B_M$ and $S_M$ permits a vertical asymptote (zero error in logarithmic coordinates) at the point determined by the above condition. This point can be determined by the following calculation:




We have:

$$B_M \; (X\,Y\,Z) \left| \begin{array}{l} \cos\left(\omega_0 t + \frac{\omega_0 T}{2}\right)\cos F_1 \\ \sin\left(\omega_0 t + \frac{\omega_0 T}{2}\right)\cos F_1 \\ \sin F_1 \end{array} \right. \quad \text{d'où} \quad B_M \; (x\,y\,z) \left| \begin{array}{l} \cos\left(\omega_0 t + \frac{\omega_0 T}{2}\right)\cos F_1 \\ \sin\left(\omega_0 t + \frac{\omega_0 T}{2}\right)\cos F_1 \cos J + \sin F_1 \sin J \\ \ldots \end{array} \right.$$

and consequently the polar angle of $b_m$

$$: \text{Arc tg}\,\frac{y_{bm}}{x_{bm}} = \text{Arc tg}\,\frac{\sin\left(\omega_0 t + \frac{\omega_0 T}{2}\right)\cos J + \sin J\,\text{tg}\,F_1}{\cos\left(\omega_0 t + \frac{\omega_0 T}{2}\right)}$$

On the other hand, the plane of the geographic meridian of $B_M$ is written as $Y = X\,tg\left(\omega_o t + \frac{\omega_o T}{2}\right)$

and consequently, in XYZ, as

$$y \cos J - z \sin J = x\,tg\left(\omega_o t + \frac{\omega_o T}{2}\right)$$

Straight line $OS_1$ for Z = 0 of polar angle Y/X. By starting with the same initial conditions as in the program given, we have

$$S_1 : \quad \Omega_s t + (L_o - c)$$
$$S_M : \quad \Omega_s t + (L_o - c) + \frac{\Omega_s T}{2}$$

and consequently the equations:

$$(1) \qquad tg(\Omega_s t + L_o - c) = (1/\cos J)\,tg\left(\omega_o t + \frac{\omega_o T}{2}\right)$$

$$(2) \qquad V = \left(\Omega_s t + L_o - C + \frac{\Omega_s T}{2}\right) - \mathrm{Arc}\,tg\left(\frac{\sin\left(\omega_o t + \frac{\omega_o T}{2}\right)\cos J + tg\,F_1 \sin J}{\cos\left(\omega_o t + \frac{\omega_o T}{2}\right)}\right)$$

Equation 1 furnishes the t where $S_1$ passes through the plane of the meridian of $B_M$.

Equation 2 makes it possible to calculate the angle corresponding to $ob_m$ with $OS_M$. A calculation program is given in the annex.

2.3.2 Convergence of the Iterative Process

However, it should be noted that, even in the case where the initial error of localization is very large at the limit of visibility, the convergence of the iterative process is satisfactory. It will obviously require more iterations in the most unfavorable cases for correcting the influence of terrestrial rotation to better than $\underline{x}$ meters. However, the minor effort of the calculations to be made and their consequent rapidity should not let this be considered as a disadvantage. As an indication, we noted in Table 3 the successive results obtained for an interval between interrogation of 200 sec., and a balloon at latitude $10^{\circ}$ when the first interrogation takes place at the limit of visibility. The satisfactory convergence of the process will be noted from examination of the Table since, even in the most unfavorable cases where the initial error may reach 500 km, the error is less than 2.5 km after the third correction and is less than 500 m at the fourth correction and on the order of one meter after the seventh correction.

## III. RESTITUTION OF LOCALIZATION

In order to obtain the position of the balloon on the surface of the earth, we need to introduce the complementary system xyz based on the earth. We take oz as passing through the axis of the poles and ox based on the meridian of Greenwich. The geographic coordinates $\varphi$ and $\theta$ are linked to xyz by

$$\begin{aligned} x &= R\cos\varphi\cos\theta \\ y &= R\cos\varphi\sin\theta \\ z &= R\sin\varphi \end{aligned} \qquad (9)$$

If we assume that, at the time t = 0 selected as time base, the meridian of Greenwich forms an angle $\nu$ with the inertial axis ox, we will have:

$$\begin{aligned} X &= x\cos(\nu+\omega_0 t) - y\sin(\nu+\omega_0 t) \\ Y &= x\sin(\nu+\omega_0 t) + y\cos(\nu+\omega_0 t) \\ Z &= z \end{aligned} \qquad (10)$$

In order to take into account the precession of the orbit, the inertial longitude $\Omega$ of the ascending node will be a function of time

$\Omega = \Omega_0 + 0{,}001624\,\rho^2\,\Omega_s\cos i\,.\,t$ with $\rho = R/R_s$

If the position of the satellite at a given instant is referenced in relation to the perigee and if, at the time t = 0, the perigee is at $\Omega_{po}$ of OK and the satellite at $\Omega_{s_o}$ of the perigee, we have $\Lambda_o = \Omega_{p_o} + \Omega_{s_o} + (\Omega_s + \Delta\Omega_p)t$

with $\Delta\Omega_p = 0{,}001624\,\rho^2\,(4 - 5\sin^2 i)\,\Omega_s/2$

We can then locate the satellite in xyz by

$$x_s = R_s \cos \Lambda$$
$$y_s = R_s \sin \Lambda$$
$$z_s = 0$$

where $R_S$ and $\Omega_s$ may have values as functions of time in the case of a non-circular orbit.

The processing of the information furnishing localization can therefore be schematized in the manner indicated in Table IV.

IV. CONCLUSION

It appears from this study that it is easily possible to compensate the errors due to terrestrial rotation and subsequently effect an accurate restitution of the localization on the earth.

It should be pointed out that this study was carried out on the assumption that the only errors introduced were those due to the rotation of the earth $\omega_o$. We shall therefore be compelled later to return to this point. We can actually expect that, when other causes of error intervene e.g., those due to the wind, it will no longer be possible to exactly compensate the errors due to $\omega_o$ because this presupposes that it is possible to exactly determine the latitude of the balloon. Actually, if the errors of localization due to other causes remain below 10 km, which is what is intended, the influence of $\Omega_o$ (missing in source) will result after correction as an error of only a few meters.

This justifies the hypothesis which we shall make hereafter, i.e., the earth a stationary in regard to the evaluation of the other errors. Terrestrial rotation will be reintroduced only subsequently when the problems of restitution arise.

TABLE 3

| | base 1 | base 2 | base 3 | base 4 | base 5 |
|---|---|---|---|---|---|
| deviation | -0;39116 | -0,19901 | -0,00687 | 0,18527 | 0,37740 |
| localization 1 | 277.206 | 84.235 | 4.920 | 166.126 | 470.958 |
| localization 2 | 43.690 | 7.091 | 4 | 5.325 | 65.661 |
| localization 3 | 6.871 | 596 | 1 | 256 | 12.051 |
| localization 4 | 1.081 | 51 | 0 | 20 | 2.143 |
| localization 5 | 165 | 5 | | 3 | 383 |
| localization 6 | 25 | 1 | | 1 | 68 |
| localization 7 | 4 | 0 | | 0 | 8 |
| localization 8 | 1 | | | | 2 |
| localization 9 | 0 | | | | 0 |

CONVERGENCE OF ITERATIVE PROCESS

orbit 900 km

T = 200 seconds

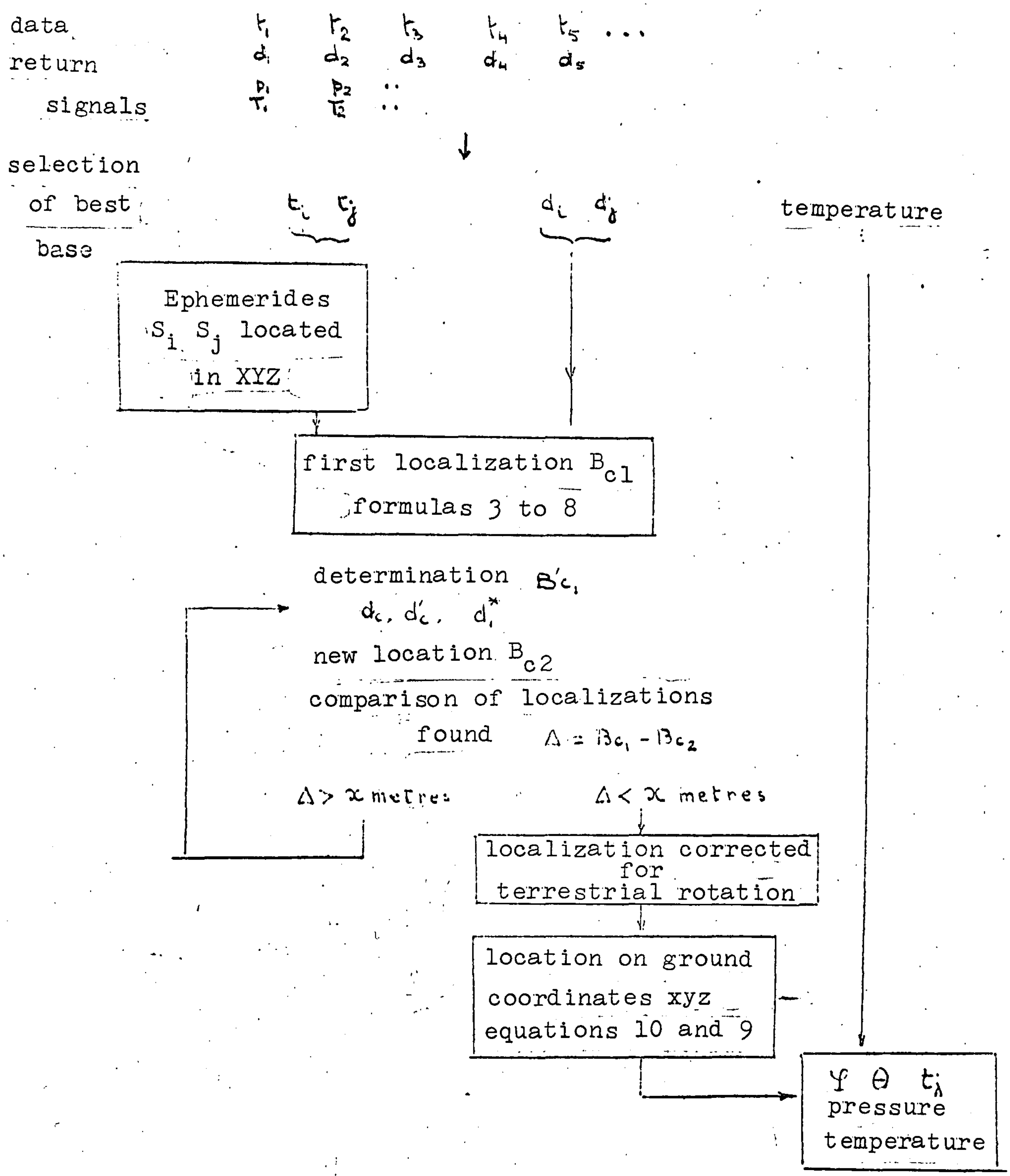
elevation zero

balloon at $10^{\circ}$ latitude

first interrogation takes place at the limit of visibility

errors are expressed in meters.

TABLE 4




COMPUTATION DIAGRAM

INFLUENCE OF TERRESTRIAL ROTATION ON LOCALIZATION

$_i$=2 X Y Z H F L

$_i$=6 S B

U=R/64(X)

P= $(398599/R^3)$

1 Read R J T $F_1$

2 Compute U P

3 State Q = 0, 00007268

4 Compute $F_2$ = ARC SIN ((SIN $F_1$)(COS J))

5 Go to 30

30 Print with 5 DEC TAB R TAB J TAB T TAB $F_1$ TAB $F_2$ RC

31 Compute C = ARC COS (1/U (COS $F_2$))

32 Compute $B_o$ = COS $F_1$

33 State $B_1$ = 0

34 Compute $B_2$ = SIN $F_1$

35 Compute $L_o$ = ARC TG ((SIN $F_1$)(SIN J)/(COS $F_1$))

36 Compute $L_1$ = $L_o$-C

37 Go to 39

39 Compute $S_o$ = U COS $L_1$

40 Compute $S_1$ = U (SIN $L_1$)(COS J)

41 Compute $S_2$ = U (SIN $L_1$)(SIN J)

42 Compute N = $(B_o - S_o)^2 + (B_1 - S_1)^2 + (B_2 - S_2)^2$;

43 Compute $B_3$ = $B_o$ COS QT-$B_1$ SIN T

44 Compute $B_4$ = $B_o$ SIN T + $B_1$ COS T

45 Make $B_5$ = $B_2$

INFLUENCE OF TERRESTRIAL ROTATION ON LOCATION (Continued)

46 Compute $L_2 = L_1 + PT$

47 Go to 48

48 Compute $S_3 = U \text{ COS } L_2$

49 Compute $S_4 = U (\text{SIN } L_2)(\text{COS } J)$

50 Compute $S_5 = U (\text{SIN } L_2)(\text{SIN } J)$

51 Compute $W = B_3 S_3 + B_4 S_4 + B_5 S_5$

52 If $W \triangleleft$ Go to 1

53 Compute $G = \sqrt{}(B_3 - S_3)^2 + (B_4 - S_4)^2 + (B_5 - S_5)^2)$

54 Compute $A = \text{ARC TG } ((B_1 + B_4) \text{ COS } J + (B_2 + B_5) \text{ SIN } j)/ (B_o + B_3))$

55 Compute $V = (L_1 + L_2)/2 - A$

56 Print with 5 Decimals TAB $L_1$ TAB $L_2$ TAB A TAB V RC

57 Go to 6

6 State $D = N$

7 Compute $K = (D^2 - G^2)/4U \text{ SIN } PT/2$

8 Compute $B_6 = D^2 (U \text{ SIN } PT/2 + K)^2$

9 Compute $M = 1 - K^2$

10 Compute $S_6 = \text{ARC COS } ((M - B_6 + U^2(\text{COS } PT/2)^2)/2U (\sqrt{}M) \text{ COS } PT/2)$

11 Compute $X_1 = K \text{ SIN } (PT/2 + L_1) + (2(1 + U^2)-(D^2 + G^2) (\text{COS } (L_1 + PT/2)) 4U \text{ COS } (PT/2)$

12 Compute $Y_1 = (K \text{ COS } (PT/2 + L_1) + (2(1 + U^2) - (D^2 + G^2)) (\text{SIN } (L_1 + PT/2))/4U (\text{COS } (PT/2)))(\text{COS } J)$
$(\sqrt{}M) (\text{SIN } S_6) (\text{SIN } J)$

13 Compute $Z_1 = (K \text{ COS } (PT/2 + L_1) + (2(1 + U^2) - (D^2 + G^2)) (\text{SIN } (L_1 + PT/2))/4U (\text{COS } (PT/2)))(\text{SIN } J) +$
$(\sqrt{}M) (\text{SIN } S_6) (\text{COS } J$

INFLUENCE OF TERRESTRIAL ROTATION ON LOCATION (Continued)

14 Compute $E = 6400\sqrt{((X_1 - B_3)^2 + (Y_1 - B_4)^2 + (Z_1 - B_5)^2)}$

15 Print with 3 Decimals TAB E RC

16 If $E < 0{,}01$ Go to 23

17 Compute $X_2 = X_1 \text{ COS } T + Y_1 \text{ SIN } T$

18 Compute $Y_2 = X_1 \text{ SIN } T + Y_1 \text{ COS } T$

19 Compute $H_1 = \sqrt{((X_2 - S_o{}^2 + (Y_2 - S_1)^2 (Z_1 - S_2)^2)}$

20 Compute $H_2 = \sqrt{((X_1 - S_o)^2 + (Y_1 - S_1)^2 + (Z_1 - S_2)^2)}$

21 Make $D = H + H_2 - H_1$

22 Go to 7

23 Make $L_1 = L_2$

24 State $B_o = B_3$ $B_1 = B_4$ $B_2 = B_5$ $S_o = S_3$ $S_1 = S_4$ $S_2 = S_5$

25 Go to 42

END

EXPLANATION OF LETTER SIGNS

R:" $R_s$ "Radius of orbit

P:" $SL_s$" Velocity of satellite rotation

R:" $\Omega_o$" Velocity of terrestrial rotation

J: Inclination of orbit

T: Interval between interrogation

$F_1$: Latitude of balloon

$F_2$: Distance from trace (at the initial instant)

C: $\partial$ " One-half arc of visibility

$B_o$, $B_1$, $B_2$: Balloon at instant 0

EXPLANATION OF LETTER SIGNS (Continued)

$B_o$, $B_4$, $B_5$: Balloon at instant T

$S_o$, $S_1$, $S_2$: Satellite at instant 0

$S_2$, $S_4$, $S_5$: Satellite at instant T

$L_o$:" $\Delta_o$" Inertial longitude of balloon $B_o$

$L_1$, $L_2$: Satellite longitudes

G: $S_1$ $B_1$"

$\Lambda$: Mean position of balloon

V: Deviation between mean positions of balloon and of satellite

K:" $\xi_*$ "

$B_3$:" $\pi^2$"

M: $\pi_b^2$"

$S_6$: $\gamma_b'$"

$X_1$, $Y_1$, $Z_1$: Balloon calculated as "B"

$X_2$, $Y_2$: Balloon calculated as "B'"

$H_1$:" $d_c'$ "

$H_2$:" $d_c$"

D: $d_o^*$"

E: Error of localization

W$\triangleleft$ Condition of visibility

INFLUENCE OF TERRESTRIAL ROTATION - CONDITION ZERO ERROR

XAF

$_{i}$=2F

P = $\sqrt{}$(398599/$R^3$)

U=R/6400

1 Read R J

2 State T=100

3 State $F_1$ = 0,087267

4 Compute A = 1/COS J

5 Compute B = SIN J

6 Compute $F_2$ = ARC SIN ((SIN $F_1$)/AX

7 Compute U P

8 Compute L = ARC TG ((TG $F_1$)B)

9 Compute C = ARC COS (1/U COS $F_2$)

10 Read X U

11 Compute Y = TG (PX + L - C)-A TG (X + T/2)

12 Make X = X + U

13 Compute Z = TG (PX + L - C)-A TG (X + T/2)

14 Make W = YZ

15 If W $<$ 0 go to 18

16 Make Y = Z

17 Go to 12

18 Make U = - 0, 1U

19 If a variant, print with 3 decimals TAB U RC

20 If (U) $<$ 0,1 go to 22

INFLUENCE OF TERRESTRIAL ROTATION - CONDITION ZERO ERROR (Continued)

22 Compute V = PX + L - C + PT/2 - ARC TG ((SIN (X + T/2))/

A + B TG $F_1$)/(COS (X + T/2))

23 Print with 5 Decimals TAB $F_1$ TAB T TAB X TAB V RC

24 Make $F_1 = 2F_1$

25 If $F_1 > 0,37$ go to 27

26 Go to 6

27 Make T = 2T

28 If T > 300 Go to 31

29 State $F_1 = 0,087267$

30 Go to 6

31 End

X: "t" Time

U: Calculation step

R: Radius of orbit

C: One-half arc of visibility

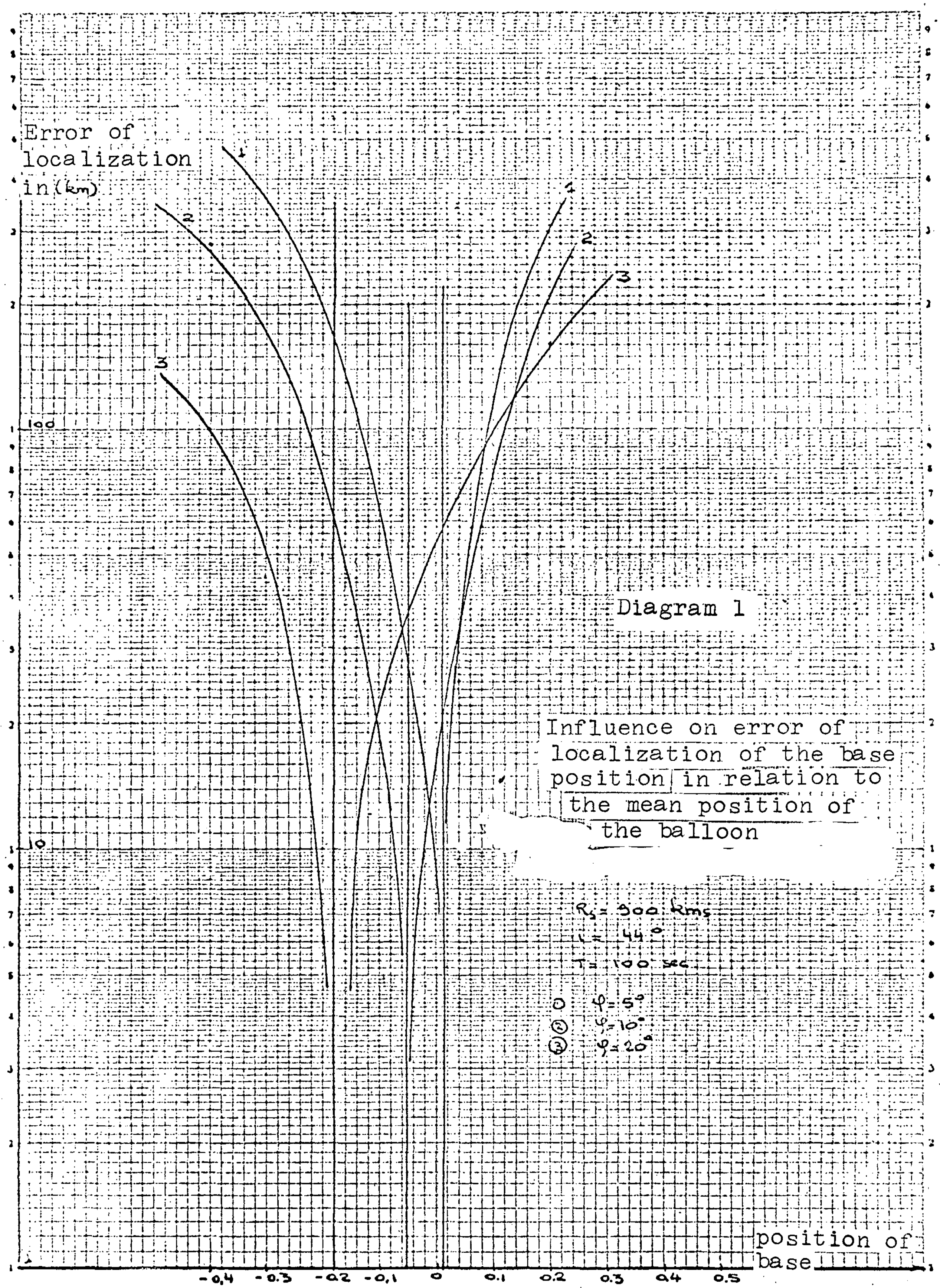
V: "$\nu$"

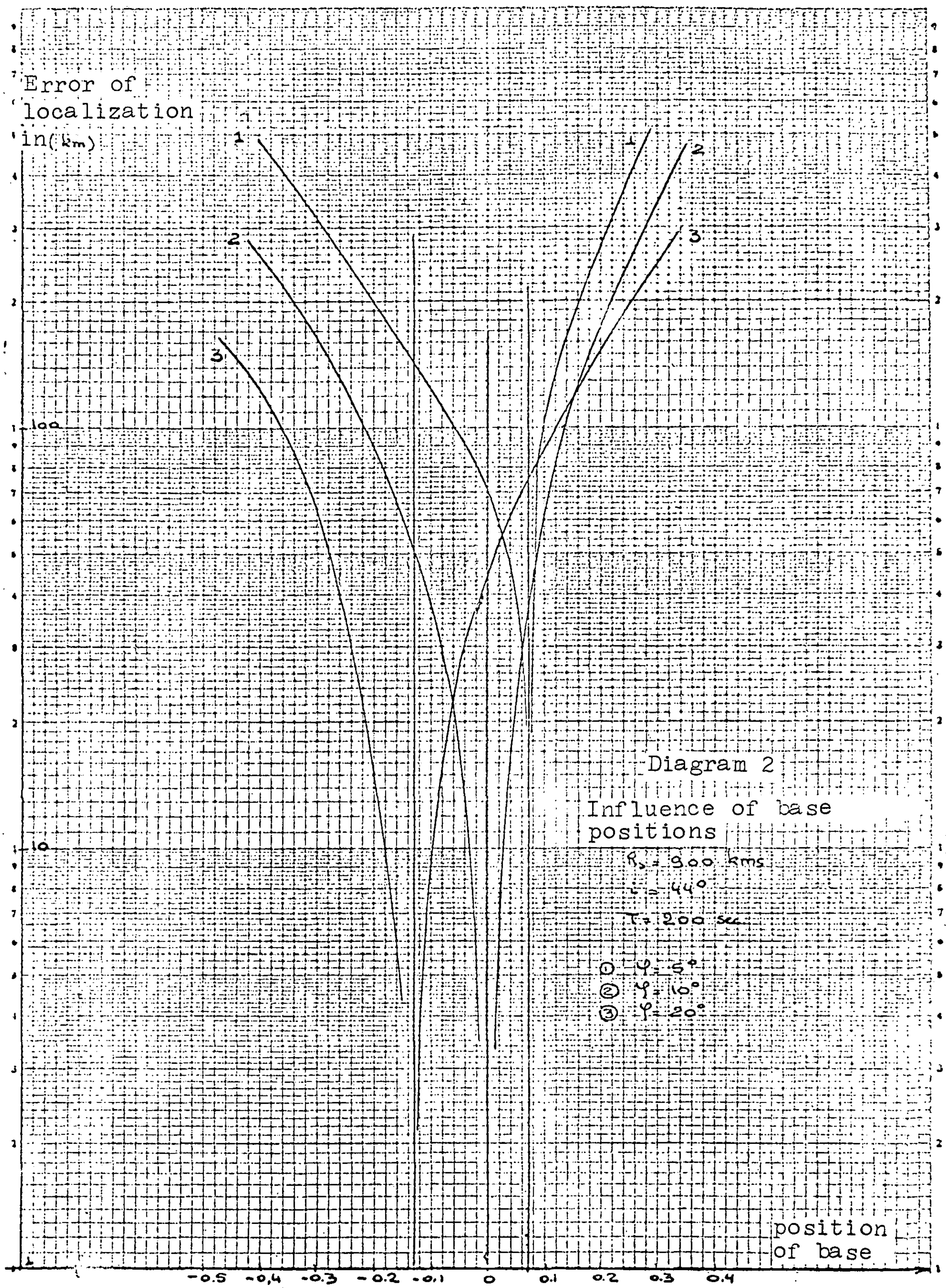
P: "$\Omega_s$"

Q: "$\Omega_o$"

J: Inclination of orbit

L: "$L_o$"


Error of
localization
in (km)
100
10
Diagram 1
Influence on error of
localization of the base
position in relation to
the mean position of
the balloon
Rs = 300 Kms
i = 44°
T = 100 sec
1 φ = 5°
2 φ = 10°
3 φ = 20°
-0,4
-0.3
-0.2
-0,1
0
0.1
0.2
0.3
0.4
0.5
position of
base


Error of
localization
in(km)
100
10
1
2
3
Diagram 2
Influence of base
positions
position
of base
-0.5
-0,4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4